BIOMEDICAL WASTE INCINERATOR TESTING PROGRAM

SUMMARY REPORT

JULY 1990

Ontario
Environment
Environnement
Jim Bradley, Minister/ministre

ISBN 0-7729-7337-7

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ARB-102-90

JULY 1990

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PIBS 1076

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Introduction:

There are currently 122 biomedical waste incinerators (BWIs) located on hospital premises in Ontario, burning general hospital and pathological waste. The waste contains variable quantities of chlorinated plastics which may generate hydrogen chloride and chlorinated toxic organics during burning. The air emissions and ash from these incinerators could also contain heavy metals, microorganisms, radioactive compounds, mutagenic compounds and products of incomplete combustion such as carbon monoxide, polyaromatic hydrocarbons (PAHs).

Biomedical waste incinerators in Ontario are small and are either batch or semi-continuously fed two-chamber types. All of them are equipped with either afterburners or secondary stage burners to keep the combustion gas at 1000°C for 1/2 second.

There is a lack of emission data pertaining to biomedical waste incinerators worldwide. The Ontario Ministry of the Environment (MOE) has initiated an extensive testing and evaluation program to generate the needed emission data for these facilities. Except for data generated in this program, there are no other air emission data for toxic pollutants from biomedical waste incinerators in Ontario.

The stack and ash sampling, and process observation component of this program was done under contract. Seven incinerators were selected for testing under this program. The consultant's final report is under preparation. This report is a summary presentation of the results and discussion of the testing carried out at five of the incinerators.

Program Description:

The selection of incinerators was based on technology in use, mode of operation and waste composition; the incinerator site being centrally located to facilitate transport of equipment to the site, and the collected samples to the ministry laboratories; and easy accessibility at the selected site. For these reasons, the five hospital incinerators tested were selected in the Toronto area and vicinity, and represented the typical configuration and operation of these units across the Province.

The selected incinerators were of batch or semi-continuous feed design, and burnt wastes of different plastic content. Two

incinerators were equipped with either a dry scrubber/baghouse or a liquid scrubber. The removal efficiencies of these air pollution controls for selected air pollutants were also measured.

Five classes of air pollutants were sampled at each incinerator, using separate sampling trains/systems for each class;

1. Semi-volatile organics such as dioxins (PCDDs), furans (PCDFs), polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorophenols (CPs) and chlorobenzenes (CBs). Selected sample extracts were tested for mutagenic activity.

2. Volatile organics.

3. Particulate loading, trace metals and gross radiation count.

4. Microorganisms, including bacterial counts and Bacillus Cereus spore spiking of the incinerators.

5. Gaseous pollutants including hydrogen chloride (HCl), nitric oxide (NO), sulphur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and total hydrocarbons (THCs).

The biomedical waste incinerator testing program was divided into four phases. Field testing of five incinerators was completed as part of the first two phases. Two sets of tests (a,b) were carried out at one of the tested incinerators (site 4) in the second phase to examine the effect of increased plastics in the waste on air emissions. The testing of two incinerators with air emission control systems at: St. Joseph's Hospital, Sarnia and DECOM facility, Gatineau, Quebec, was carried out in phases 3 and 4. These results were not available to be included in this summary report.

The five incinerators tested in phases 1 and 2 are located at the following sites:

York Central Hospital, Richmond Hill	site 1
Humber Memorial Hospital, Weston	site 2
Women's College Hospital, Toronto	site 3
Toronto Western Hospital, Toronto	site 4(a & b)
Oakville-Trafalgar Hospital, Oakville	site 5

These site numbers are used throughout the report to identify the incinerators at these sites.

Laboratory Services Branch coordinated the analytical work and provided the majority of chemical and biological analyses. Zenon Analytical Services performed the analyses for volatile organics. Clayton Environmental Consultants carried out stack sampling, and process observation. The Air Resources Branch provided continuous

emission monitoring (CEM) and the overall program coordination. The Radiation Protection Laboratory of the Ministry of Labour carried out the radiation measurements.

Sampling and Analyses:

Stack sampling was carried out in accordance with the Ontario Source Testing Code (1): sampling locations were at sufficient distances from obstructions and bends for the collection of representative samples: isokinetic multi-point sampling was carried out in the case of particulate pollutants: the operation of the incinerators was monitored during the tests.

A Method 5 sampling train of the Ontario Source Testing Code was modified for sampling of specific classes of pollutants. All sampling train components were calibrated, prewashed and proven prior to field sampling.

A condenser containing an XAD-2 trap was inserted between the filter and impingers of the Method 5 train for semi-volatile organics. All internal surfaces of the train in contact with the extracted samples were lined with glass except for the nickel plated sampling nozzle. An expanded ASME protocol (2) was followed in the analysis of the collected samples.

An aliquot of the initial sample extract of one out of the three tests on each incinerator was tested for mutagenic activity. The Ames Salmonella mutagenicity test was used as a screen for mutagenic activity in emission and ash samples. Each Ames test was conducted with strains TA 98 and TA 100 both with and without metabolic activation (S-9). Measurement of activity in any strain combination was considered detection of mutagenicity.

Volatile organics, with boiling points of less than 150°C were sampled with a volatile organic sampling train (VOST) following the slow-VOST procedure (3). Samples were extracted at a point of average stack gas velocities for 40 minutes at 0.5 l/minute.

Water, nitric acid and potassium permanganate were placed in the impingers of the Method 5 sampling train for particulate, hydrogen chloride, mercury and other trace metals(4). Alpha, beta and gamma activities of the samples were measured as soon as possible after the sample collection. The samples were then subjected to a semi-quantitative elemental scan using direct current plasma.

In order to prevent dehydration of bacteria during sampling,the filter was omitted from the Method 5 sampling train for microorganisms (5). A buffer consisting of K_2HPO_4 and KH_2PO_4 was placed in the impingers. Substrates containing Bacillus Cereus spores were mixed with waste prior to burning in the incinerators. All continuous emission monitors for opacity and gaseous pollutants

were used in accordance with either the Ministry's guidelines or the U.S. Environmental Protection Agency guidelines or the manufacturers instruction manuals.

A sample extraction probe with a coarse particulate filter was used for gas sampling. Additionally a fine particulate filter preceded the THC and HCl analyzers.

Three separate heated sampling lines were used. One led to a flame ionization analyzer for THCs. The second led to heated impingers containing concentrated sulphuric acid for water removal, then to a non-dispersive infrared absorption analyzer with a correlation gas filter for HCl measurement. The third led to a condenser (for water removal) then branched into five analyzers working on the following principles: paramagnetic resonance for O_2, chemiluminescence for NO_x, non-dispersive ultraviolet absorption for SO_2 and non-dispersive infrared absorption for CO and CO_2.

Provisions were made for injection of certified calibration gases at points prior to the coarse filter and before each analyzer.

Description of incinerators:

Incinerator 1 is a two-stage Plibrico batch unit designed to burn 750 kg of biomedical waste per batch; its primary chamber is operated in the excess air mode. Anatomical waste is incinerated in a pathological chamber with a separate burner located within the primary chamber. An afterburner is installed in a horizontal flue duct.

Incinerator 2 is a two-stage Plibrico, excess air batch unit. Its primary chamber contains a separate small chamber with an additional burner for incineration of pathological waste. The secondary chamber is a vertical flue duct with an afterburner. This incinerator is designed to burn 850 kg of waste per batch.

Incinerator 3 is a Trecan Combustion's semi-continuous feed two-chamber, controlled air model Trecare II, designed to burn 160 kg/h of biomedical waste or 55 kg/h of pathological waste. The primary chamber is operated under starved air condition.

Incinerator 4 is a controlled air, two-chamber Consumat C-325 semi-continuous feed unit, designed to burn 267 kg/h of biomedical waste. The primary chamber is presently operated with excess air.

Incinerator 5 is a Francis Hankin two stage excess air batch unit. The incinerator is equipped with a pathological chamber, physically separated from the incinerator, with a burner and a flue duct connected to the primary incinerator chamber.

Results:

The results indicate that for the five biomedical waste incinerators tested, the air emissions greatly depend on whether the unit is of the batch or semi-continuous feed design. The time-emission patterns of gaseous pollutants and the particulate emission rates measured for the two designs are different in shape.

Typical plots of continuously monitored levels of opacities and CO in the stack emissions of a batch type Incinerator 2 and a semi-continuously fed Incinerator 3 are shown in Figures 1 and 2.

For Incinerator 2, peaks of high levels of both pollutants were recorded at the start of the burn. The levels stayed low for the rest of the batch until approximately four hours after start-up when they started to rise again as a result of shutting off the afterburner. Similar patterns were recorded at the other two batch Incinerators 1 and 5.

At the semi-continuously fed Incinerator 3, the peaks occurred more frequently throughout the testing period, with significantly higher opacity levels in comparison to Incinerator 2. The occurrence of opacity peaks at Incinerator 3 coincided with the waste pushes into the incinerator.

The emission patterns of CO and opacities at the other semi-continuously fed Incinerator 4 were similar to those shown in Figures 1 and 2.

The average stack levels of selected pollutants are shown in Tables 1, 2, 3 and 4. Significantly higher levels of most pollutants were measured at the two semi-continuously fed Incinerators 3 and 4 in comparison to the tests carried out at the batch Incinerators 1 and 2.

TABLE 1: Average Stack Concentrations Measured by Continuous Emission Monitors

Incinerator Site	NO (mg/m^3)	CO (mg/m^3)	THC (ppm)	SO_2 (mg/m^3)	HCl (mg/m^3)
1	90	49	3	68	600
2	80	118	18	69	757
3	119	47	16	76	2090
4a	65	126	9	107	1010
4b	96	102	4	105	699
5	74	123	10	68	2250
MOE Regulation 308 standard			100		50*

* MOE Policy for new incinerators

TABLE 2: Average Stack Concentrations of Organics Based on Three Tests.

Incinerator Site	PAH (ug/m^3)	CB (ug/m^3)	PCB (ug/m^3)	CP (ug/m^3)
1	3	0.4	ND	NA
2	37	0.6	0.1	0.5
3	ND	22.6	1.2	87.5
4a	ND	6.3	0.5	NA
4b	ND	4.9	0.4	33.9
5	ND	4.0	0.2	14.8

ND= non detectable
NA= not available

TABLE 3: Average Stack Concentrations of Particulates and Metals Based on Three Tests.

Incinerator Sites	Particulates (mg/m^3)	Metals (Total) (mg/m^3)	Cadmium (mg/m^3)	Lead (mg/m^3)	Mercury (mg/m^3)
1	77	23	0.1	2.2	1.2
2	87	21	0.1	1.4	1.8
3	307	59	0.7	11.5	0.6
4a	619	98	0.7	10.5	1.1
4b	705	88	0.8	12.2	0.3
5	1210	52	0.2	5.5	0.9
*MOE Policy for new incinerators.	20*				

TABLE 4: Average Stack Concentrations of Dioxins(And Furans) and Mutagenicity.

Incinerator Site	Dioxin Total (ng/m^3)	Dioxin Toxic Equivalents[1] (ng/m^3)	Mutagenicity Stack ($rev*/m^3$)	Mutagenic Density/Ash ($rev*/m^3$)
1	34	0.9	3300	101
2	263	6.9	(10694)**	299
3	685	19.7	(3248)**	206
4a	909	32.5	ND	4094
4b	1024	33.1	(169)**	242
5	1346	52.4	(3293)**	902

1= Equivalents calculated using the international toxicity equivalency factors North Atlantic Treaty Organization/Committee on Challenges of Modern Society (NATO/CCMS), Report no. 176/1988a.
*rev= revertants
( )**= values may be overestimates.

Tests with different waste fed to Incinerator 4 showed somewhat higher stack levels of most measured pollutants in tests 4b when the waste contained more plastics.

However, the highest stack concentrations measured in the program were those at the batch Incinerator 5. The reason for these higher emissions is unknown except that this particular batch type incinerator is of a different make than the other two batch Incinerators 1 and 2.

A summary of the results of Ames testing of the six incinerator samples is shown in Table 4. Positive results were obtained on the emission particulates from the Incinerators 1 and 2 and on the volatile portions of the organics emitted from the Incinerators 2, 3, 4b, and 5. No mutagenic activities were detected in either particulate or volatile fractions from the Incinerator 4a tests. Mutagenic activity was detected in the ash samples from all five incinerators.

No microorganisms were found in air emissions at any of the tested incinerators during or before incinerator operation. No spores of the challenge organisms were found in the ashes. Some bacteria were recovered from the ashes but this was likely related to the recontamination of the ash during the cool-down period. Bacteria similar to those in the ash were recovered from the samples of ambient air around the incinerators. Little clinical significance could be attached to any of the bacterial strain recovered.
No radioactivity (alpha, beta or gamma activity) was reported to be present above the background levels on either particulates or impinger extracts of the collected stack samples.

The stack emissions from all five incinerators were subjected to dispersion calculation to compare the calculated levels at critical receptors with the MOE point of impingement (POI) standards and guidelines. The results are shown in Table 5.

TABLE 5: Calculated Point of Impingement Concentrations

Incinerator Site	Particulates (ug/m^3)	Dioxin (pg/m^3)	Lead (ug/m^3)	Mercury (ug/m^3)	HCl (ug/m^3)
1	11	0.5	0.3	0.2	87
2	14	7	0.2	0.3	50
3.	83	396	3.1	0.2	566
4a	9	23	0.2	<0.1	14
4b	12	27	0.2	<0.1	11
5	23	13	0.1	<0.1	42
MOE Reg. 308 Standards/Guidelines	(100)	(450)	(10)	(5)	(100)

The calculated POI concentration of HCl for the Incinerator 3 exceeded the MOE standard. The short stack height above the building at that site, and the proximity of the POI are the main causes of the elevated POI concentration. The hospital at that site has shutdown its incinerator and is investigating alternatives for disposal of the waste including ways to bring the incinerator into compliance with the HCl standard.

The results of the standard MOE leachate tests on the ash samples collected during stack tests are shown in Table 6.

TABLE 6: Summary of Ash Leachate Tests

Incinerator Site	Boron (mg/l)	Barium (mg/l)	Cadmium (mg/l)	Lead (mg/l)	Chromium (mg/l)
1	4	0.2	<0.1	<0.1	<0.1
2	12	0.2	0.3	<0.2	<0.1
3	3	0.3	<0.2	0.4	2.1
4a	2	>6.1	<0.2	<0.7	<0.1
4b	1	1.1	0.3	<0.6	<0.1
5	<0.1	<0.1	<0.1	<0.1	<0.1
Schedule 4 (Reg 309) Criteria	5	1	0.005	0.05	0.05

The levels of metals in Table 6 are not exceeding the Regulation 309 Schedule 4 criteria by more than a factor of 100. If exceeded, the ash would be classified as a hazardous waste under this regulation.

Conclusions:

The levels of pollutants in both air emissions and ash in all the five tested hospital incinerators, with one exception, were found to be in compliance with the existing Ontario MOE point-of-impingement (POI) standards and guidelines. The one exception being that HCl emissions from the incinerator at site 3 resulted in a calculated POI concentration above the MOE standard of 100 ug/m3. The hospital at that site has shutdown its incinerator and is investigating alternatives for disposal of the waste including ways to bring the incinerator into compliance with the HCl standard.

The MOE ash leachate criteria were not exceeded in tests at any of the tested hospitals. All ash samples were found to be within the toxic leachate criteria under Regulation 309.

However, the Ministry policy 01-03, for new incinerators, stack concentrations limits for particulate and hydrogen chloride were exceeded for all incinerators tested, largely because of the lack of appropriate air pollution control equipment such as scrubbers followed by particulate removal devices.

The levels of particulate, metals, dioxins and furans and hydrogen chlorides at almost all hospital incinerators tested were higher than those measured at large well designed and operated municipal incinerators equipped with scrubbers and particulate removal devices (6). It must be pointed out, however, that because hospital incinerators are generally of small size (the largest units tested have a capacity 6.4 tonnes per day), and shorter daily operation periods, the total amount of air pollutants emitted from a hospital incinerator would be expected to be much lower than that from most municipal incinerators.

An additional contributor to the high pollutant levels is unsteady combustion brought about by intermittent feeding of semi-continuously fed incinerators and bursts of incomplete combustion occurring immediately after igniting waste in fully loaded batch incinerators. Since these bursts of incomplete combustion occur more frequently at semi-continuously fed incinerators, the aggregate result over the test periods were higher pollutant levels in comparison to batch incinerators.

References:

1. Source Testing Code (Version #2), Ontario Ministry of the Environment November,1980.

2. ASME (Draft) Protocol Sampling for the Determination of Chlorinated Organic Compounds in Stack Emissions, 1985.

3. Protocol for the Collection and Analysis of Volatile POHCs using VOST, E.P.A. Report 600-8-84-007, March 1984.

4. A Method to Measure Emissions of Particulate Matter, Metals and Hydrogen Chloride from Stationary Sources, Environmental Protection Service, Environment Canada, April 1985.

5. Stack Sampling Method (Draft) for Determination of Emissions of Microorganisms, Ontario Ministry of the Environment, 1988.

6. The National Incinerator Testing and Evaluation Program: Air Pollution Control Technology Report, Environmental Protection Service 3/UP/2, September 1986.

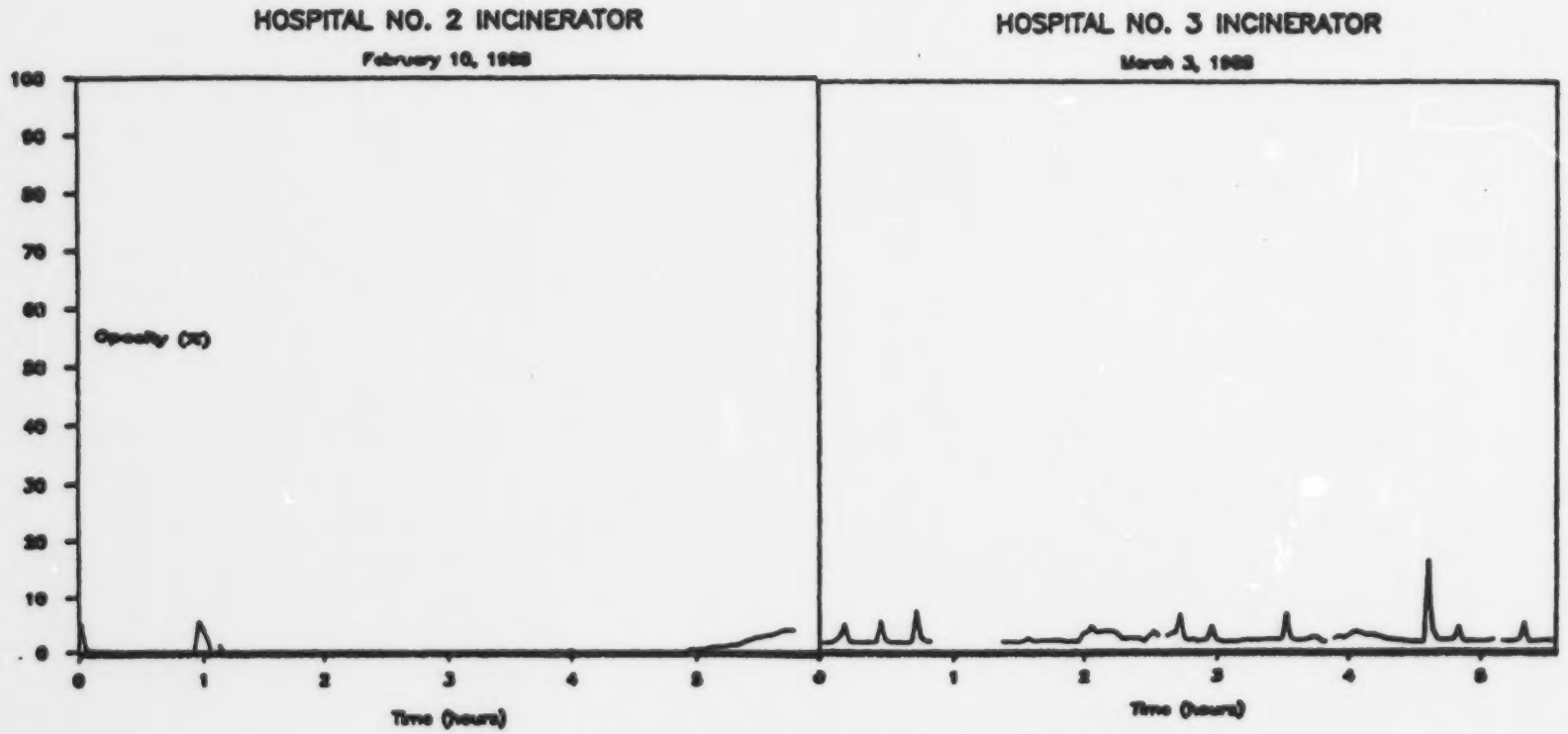

Figure 1: OPACITY vs TIME

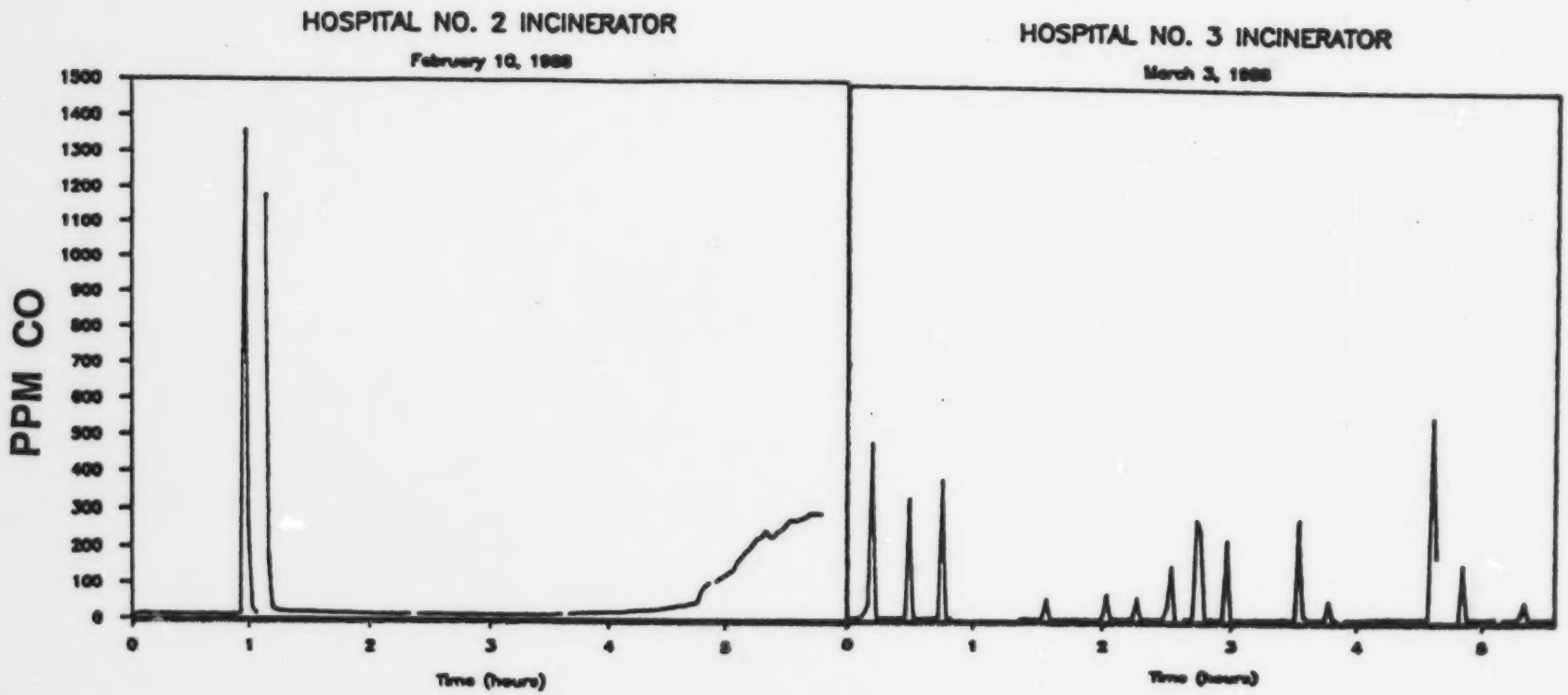

Figure 2: CARBON MONOXIDE vs TIME